

EDUCATION, RESEARCH AND TECHNOLOGY

A substantial number of public and private programs have been developed in California to help educate the general public about ocean resources. Formal curricula in ocean sciences now exist for children in Kindergarten through Grade 12 and for students within California's colleges and universities. In addition to educational programs, ocean research is conducted through a variety of programs at the college and university level. The Sea Grant programs in California provide valuable guidance and funding for a variety of ocean research and education programs throughout the State. The programs encourage and support scientifically sound research that addresses key ocean and/or coastal resource management, policy, science, or engineering issues that face the State of California now or in the reasonably foreseeable future.

Exciting challenges await the research community with the need to better understand the ocean ecosystem and the vast potential for developing new and innovative ocean technologies. This information and technology development will play an important role in achieving the ocean stewardship goal identified in this Agenda. Additionally, this research can help achieve economic goals by providing the technical basis for encouraging environmentally sound, sustainable, and economically beneficial ocean resource development activities. Key to this success is making the results of research and technology development activities readily available.

Ideally, California's natural resource managers should have at their immediate disposal the best available data and information for resource management, planning, and regulatory efforts. However, in reality these managers are often forced to develop plans or implement regulatory policies based on generalized, incomplete, and sometimes inconsistent information. Technologies currently in place or being developed are revolutionizing the way we gather and analyze information about California's natural resources. This subchapter describes four related subjects: education, research, emerging technologies and information technology. These fields are vital components of comprehensive ocean resource management in California.

BACKGROUND

Education

California has a variety of high quality ocean education programs which serve the general public. For instance, such world renowned facilities as the Steinhart Aquarium at the Academy of Sciences in San Francisco, Monterey Bay Aquarium in Monterey, and Stephen Birch Aquarium-Museum at the Scripps Institution of Oceanography at the University of California at San Diego, offer excellent educational opportunities through lecture series, laboratory seminars, hands-on activities, traveling displays and programs, and field trips. Other educational programs geared to the general public include a variety of government and non-profit ocean education programs including Adopt-A-Beach and the CoastWeeks program run by the California Coastal Commission (Coastal Commission) which provide education opportunities while helping to keep trash and debris off California beaches.

Ocean education programs are also offered at many local, State, and federal parks, reserves, refuges, and sanctuaries throughout California, such as through the California State Park System. One of the nation's leading providers of outdoor recreation programming, State Park System educational opportunities range from daytime and overnight school-sponsored field trips to Junior Lifeguard training and environmental living programs. Each year schools throughout California use state parks as natural and cultural history learning centers for hundreds of thousands of school children. Over 1.3 million hours of annual formal instruction occur in state parks from the North Coast Redwoods to Old Town San Diego.

The California Department of Education (CDE) maintains an Environmental Education Office for K-12 programs as required by the California Education Code (Section 8721). This office develops and disseminates information about educational opportunities specifically related to the conservation, interpretation and use of natural resources within the State of California, as well as administers the Environmental Education Grant Program funded by the Environmental License Plate Fund. This program has resulted in numerous resources for K-12 educators including model curricula, professional development, student action projects, educational resource manuals, and the California Environmental Education Interagency Network.

Specifically, ocean science is now a component of the recently revised "California Science Framework of K-12" curriculum. Topics in ocean education have proven to be engaging for students that otherwise show little or no interest in traditional science subjects, and the curriculum offers unique opportunities to use the students' new interests for improving skills in math, reading, writing, and social science. CDE's Science and Environmental Education Unit has also produced environmental education compendia in cooperation with the California Resources Agency, the California Environmental Protection Agency, and other agencies. The six compendia cover water resources, energy resources, integrated waste management, human communities, air quality, and natural communities. The natural communities compendium includes programs in the ocean sciences.

Research

At the college and university level, the "Directory of Academic Marine Programs in California" (California Sea Grant College 1993) identifies approximately 50 marine science and research programs in California (including both two- and four-year programs). Some of the major programs include the Scripps Institution of Oceanography at the University of California (UC) at San Diego, Hancock Institute for Marine Studies at the University of Southern California (USC), Southern California Marine Institute in Long Beach (a cooperative program between California State University [CSU], USC, and Occidental College), Marine Science Center (within UC Los Angeles), Moss Landing Marine Laboratories (within CSU), Hopkins Marine Station in Monterey (within Stanford University), Santa Barbara Marine Science Institute (within UC Santa Barbara), Bodega Bay Marine Lab (a cooperative program between UC Davis and UC Berkeley), Long Marine Lab (within UC Santa Cruz), Humboldt State Marine Research Program (within CSU), and the Romberg Tiburon Centers (within CSU). The marine research programs at these institutions cover a variety of scientific disciplines, including physical oceanography, biological oceanography, marine biology, marine geology, geophysics, marine chemistry, applied ocean sciences, and coastal economics.

Independent research labs not directly affiliated with universities or colleges conduct important ocean research. For instance, private sector developments in the field of marine biotechnology show promise for medical and industrial applications. Private sector ocean research is often generated during technical development studies, in preparing environmental data for project applications, or in complying with federal, state, or local government permit requirements. Several non-profit research companies and environmental organizations also contribute to California's ocean research inventory. Ocean research is also conducted by state and federal agencies, such as the State Water Resources Control Board, California Department of Fish and Game, Office of Oil Spill Prevention and Response, U.S. Fish and Wildlife Service, U.S. Minerals Management Service, and National Oceanic and Atmospheric Administration.

Emerging Technologies

Technologies that are often taken for granted today were once considered speculative, new or "emerging" in recent history. Submersible vehicles can traverse the ocean floor thousands of feet below the surface, underwater cameras and viewers can go where humans are still unable to venture, and offshore oil and gas development can now take place in deep ocean waters previously thought to be inaccessible. Funding and research for such technologies by the military, other government agencies and the private sector have been

on the decline for many years, slowing the development of new technologies that could be helpful for ocean and coastal resource protection, industrial development, and resource management.

Information Technology

Ocean resource managers have the responsibility to steward, monitor, and track physical and biological resources that may lie above, below, or on the surface of the sea, in addition to the land resources that impact the ocean ecosystem. For the regulated community, project costs on land or offshore can increase if environmental, economic, engineering, or regulatory information necessary to determine project feasibility or acceptability are not readily available. Timely access to geographically located information is critical for both policy makers and others who need to rapidly assemble the complicated scientific, planning, or regulatory processes that apply to a certain geographic area.

Information about the earth's surface has been placed on maps for thousands of years. However, the complexity of information and its use has evolved substantially in recent times. Originally, maps were used primarily to depict the cosmos, specify land ownership or as aids to navigation, but they have become increasingly important for depicting jurisdictional boundaries, land uses, vegetation, topographic hazards, social and demographic data, population and natural resources distribution, air and water quality patterns, and many other features relevant to public and private decision making. The complications involved with maintaining all this information on one map required the development of theme, or thematic, maps to display specific categories of information. For a resource manager this could mean having a set of maps for wetlands, another for topography, and yet another to depict jurisdictional boundaries.

A computer-assisted geographic information system (GIS) allows multiple sets of information to be placed on a series of electronic maps which can then be viewed and manipulated alone or in combination with other thematic information layers. This tool becomes particularly important for ocean resource management because multi-dimensional data about the ocean surface, water column, and ocean floor can be displayed and analyzed individually or together on computer-generated maps, and can be quickly modified and redisplayed, rather than requiring hours or days to edit or revise a map. Resource managers, researchers, private industry, and members of the public are also interested in gaining rapid access to natural resource data and in the ability to transfer data immediately to specific locations where it can be used. Significant GIS facilities exist at the UC Berkeley, UC San Diego, UC Santa Barbara, University of Southern California, and other academic institutions in California.

ISSUE ANALYSIS

Science has contributed much to understanding the ocean ecosystem, but more is yet to be learned. Additional research about activities and processes which affect the ocean ecosystem will be fundamental to achieving the goals established for the California Ocean Resources Management Program. Technology development will also play a role in achieving these goals. An important complement to research and technology development is education, for successful ecosystem management in the long-term requires an educational system that teaches people how to appreciate and understand nature's complex inter-relationships. It is an educated and informed public which provides the essential support for political, civil and private participation that leads to effective ecosystem management.

Education Programs for K-12 and the General Public

Some ocean education programs in California for K-12 have received national attention due to their high quality, such as the Lawrence Hall of Science Marine Activities Resources and Education project and the education programs offered through the Monterey Bay Aquarium. These and many other programs are actively networked with the National Marine Educators Association, regional Southwest Marine Educators Association, California Aquatic Science Education Consortium, American Association of Zoological Parks and Aquariums, and other organizations.

The Save Our Seas educational curriculum developed by the non-profit Center for Marine Conservation and the Coastal Commission addresses the effects of marine debris and polluted runoff (nonpoint source pollution) through hands-on projects in art, geography, language arts, mathematics, science, and social science. The program curriculum, developed with the assistance of the California Marine Debris Steering Committee's Educational Subcommittee, provides information to be presented both within the classroom and in the field. Another example of an excellent educational curriculum addressing ocean protection issues is the *No Waste Anthology-A Teachers Guide to Environmental Activities*, developed by the State Department of Toxic Substances Control's public education program. A popular marine education curriculum used primarily for K-6 is the USC Sea Grant Institution's *Wet and Wild* program. With lesson plans in both English and Spanish, the curriculum is published in association with the National Evaluation, Dissemination and Assessment Center for Bilingual Education at the California State University, Los Angeles.

Although many programs provide ocean resource curricula to students and educators, it has been difficult to ensure that these programs make their way to the classroom. Many organizations have made concerted efforts to inform the public about the availability of ocean education programs and publications. The California Department of Education completed the *California Environmental Education Resource Guide* in 1995 as well as the six compendia described earlier, and has worked to ensure their availability to classroom teachers through a variety of forums.

A series of ocean and coastal educational resource directories have been published for the South Central Coast (Santa Barbara, Ventura, and San Luis Obispo counties), San Francisco Bay and Monterey Bay areas in a cooperative effort between the Coastal Commission and National Oceanic and Atmospheric Administration's Sanctuaries and Reserves Division. These directories identify organizations which provide information or resources on marine and coastal education, including publications, audio-visuals, teacher in-service, interpretive displays and exhibits, travelling programs, or bilingual programs. It is increasingly important for similar directories to be developed in other areas of the California coastline and for these directories to be accessible through such systems as the Resources Agency's California Environmental Resources Evaluation System.

University Education

California has a substantial ocean and coastal science research capacity throughout its colleges and universities, yet it does not have a graduate education program focused upon ocean and coastal policy. Basic and applied research are necessary for furthering California's ocean and coastal resource management goals. However, different methods of training are required for individuals engaged in policy formulation.

Historically, State agencies have participated in numerous ocean policy and regulatory debates regarding such diverse issues as siting offshore liquefied natural gas terminals, coastal power plants, and offshore oil and gas facilities; mining deep ocean minerals; burning toxic chemicals offshore; dumping port and harbor dredge materials; managing fishery stocks; and disposing decommissioned nuclear submarines offshore. Managing these issues requires interdisciplinary approaches which combine ocean and coastal science, engineering, law, economics, and policy analysis. Ocean and coastal policy graduate education programs provide the interdisciplinary training necessary to help students analyze and develop approaches for addressing complicated ocean resource management issues. California has much to learn from other states that have ocean policy graduate education programs, including the universities of Oregon, Washington, Hawaii, Rhode Island, Delaware, Virginia, and Miami, and Oregon State University.

One cost-effective way the State and federal governments can promote greater interest and activity in marine-related education is by improving financial support for students through increased scholarships, fellowships and traineeships. This financial assistance leads to larger numbers of students in the field and additional support for researchers.

Program Development and Funding for Research

Sound research (both basic and applied) is the foundation for good policy and is a necessary basis for many decisions regarding the use and protection of ocean and coastal resources. Science, however, does not always influence policy rapidly, even when the more scientifically sound approach is clear. Even so, research and education must remain a priority if we are to effectively manage our ocean ecosystem.

The goals of ecosystem management (discussed in greater detail in the chapter titled, “Habitats and Living Resources”) cannot be achieved without adequate knowledge of the factors that contribute to or detract from the health of California’s ocean ecosystem. Monitoring and research projects in ocean, coastal, and inland watershed environments are vital to understanding the impacts of human and natural activities, and for determining if modifications are necessary to reduce or prevent such impacts. Ocean and coastal research activities are conducted in California by a broad spectrum of entities, including universities and colleges, industry, non-profits, and the State and federal governments. Many of California’s State ocean and coastal research dollars are spent through departmental budgets, such as the Department of Fish and Game, State Water Resources Control Board, Department of Boating and Waterways, and Department of Parks and Recreation. However, there are several specific programs that California funds or participates in which stand out in ocean ecosystem research.

Sea Grant Programs. The National Sea Grant College Program (Sea Grant Program), created through the National Sea Grant College and Program Act of 1966 (as amended in 1976 and 1987), has established a unique network of ocean research and outreach partnerships between federal, State, and local governments, academic institutions, and the private sector. The Sea Grant Program provides funding to institutions in 29 states for improving the understanding of ocean resources and developing strategies for sustainable ocean resource development, management, and conservation.

California has benefited substantially from the Sea Grant Program through research in fisheries, mariculture, marine biotechnology, marine engineering, water quality, recreation, and ocean policy and management. The Sea Grant programs in California comprise the California Sea Grant College System (UC Sea Grant; administered by the University of California), and the USC Sea Grant Institutional Program (USC Sea Grant; administered by the University of Southern California). Highly regarded by representatives of both the public and private sector, the Sea Grant programs in California were awarded \$4 million dollars in federal funds (or roughly 8% of the national program funds) for the 1995-1996 funding cycle through a nationally competitive process, and will match these funds with approximately \$2 million dollars in State and private funds.

The California Secretary for Resources administers State matching funds for projects that qualify for Sea Grant Program funding. Public Resources Code Section 6217 establishes the Resources Agency Sea Grant Advisory Panel (RASGAP), with representatives from the marine industry, resource management agencies, academia, and the legislature, to advise the Secretary on the most appropriate use of funds. The RASGAP is also charged with identifying State needs which might be met through Sea Grant research projects, reviewing all applications for funding, periodically reviewing the progress of research projects, and making recommendations to the Secretary for Resources with respect to program goals and implementation. In 1994, the RASGAP completely revised its policy and research needs statement to emphasize the development of sound scientific research that can be applied to ocean resource management needs of the State (included as Appendix K). Still missing is a more focused annual process to identify California’s research needs and to make this information available to researchers prior to soliciting research proposals. The Sea Grant Program has encouraged the State to establish an annual list of priorities to ensure that funds are being used in subject areas which support the work of ocean and coastal resource managers and decision-makers.

State legislation authorizes \$525,000 in State funds for 1996-97 to support the Sea Grant programs in California (although the appropriation has been as low as \$319,000 in the past few years). Another

\$100,000 has been appropriated for the Sea Grant Extension program which funds marine advisors and specialists located up and down the California coast. State matching funds are necessary to attract the federal dollars administered by the Sea Grant Program.

Sea Grant Advisory Services. Sea Grant's mission includes an effort to provide effective communication between university-based research programs and the users, policy-makers, educators and public who can benefit from the information generated by these programs. Through Sea Grant's Outreach and Extension services, the results of scientific research are communicated to those that apply them, and the problems and needs of these groups are communicated to Sea Grant researchers. Thus, Sea Grant plays an important role in identifying problems, finding potential solutions, and providing education for a wide range of people. Both the University of California and the University of Southern California Sea Grant programs incorporate these services into their activities.

The University of California Cooperative Extension Marine Advisory Service Program places seven marine advisors in coastal counties and two campus-based specialists, who are all part of UC Cooperative Extension. These advisors encourage the adoption and implementation of new behaviors, practices and technologies in coastal resource management, fisheries, seafood technology, aquaculture and marine education. They also identify additional research and education needs. Methods used range from publications, workshops and computer-based communications to demonstration research. The advisors annually work with over 300 cooperating organizations in government, industry and academia.

Recent projects especially beneficial to the State include technical advice and training for agencies, researchers, and others in applying geographic information systems and other methods to coastal water quality and resource management problems. The advisor service assisted a community-based salmon project used by CalTrans in Del Norte County to re-route new freeway construction at a savings of approximately \$15 million, and assisted in making federal Endangered Species Act listing of spring-run Chinook salmon unnecessary to date. Additional special projects include providing critical information on marine protected areas, fisheries management, oil/fisheries conflicts, seafood safety and exotic species.

The University of Southern California Sea Grant Institutional Program's outreach component includes a Marine Advisory Services Leader. In collaboration with Sea Grant professionals the Marine Advisory Services Leader provides information about marine pollution, threats to human health, and threats to the health of the marine ecosystem to such local stakeholders as water quality agencies, businesses, marine resource managers, and environmental organizations. Methods used range from printed material, workshops and symposiums to personal contacts and memberships in professional organizations. The USC outreach program works in partnership with local agencies and businesses to identify new research needs.

In addition, the USC outreach program develops and distributes science curricula, and provides teacher training to local educators in grades K-12. Hands-on workshops in the classroom are provided to teachers through the Sea Grant Pathfinder and Island Explorers Programs, developing teacher confidence and expertise in teaching science. Marine science and environmental education is also fostered in children through educational videos and cooperative efforts with other environmental education programs and organizations such as the California Coastal Commission, Malibu Foundation, YES Program, California Aquatic Science Education Consortium, and National Marine Educators Association.

California Marine Ecological Reserves Research Grant Program. The California Marine Resources Protection Act (MRPA) authorized approximately \$1 million for research on marine resource enhancement and management to be conducted in four coastal ecological reserves (Punta Gorda Ecological Reserve in Humboldt County, Big Creek Ecological Reserve in Monterey County, Vandenberg Ecological Reserve in Santa Barbara County, and Big Sycamore Canyon Ecological Reserve in Ventura County). The ecological reserves differ widely in physical features and biology, as well as in the socio-economic characteristics of nearby communities.

General research topics have been established by the DFG, such as marine reserves as a resource management tool, fish community and population studies, and harvest resilience. The UC Sea Grant was selected in June of 1996 to administer this program. In awarding grants, the UC Sea Grant will establish a special panel of scientists and other professionals for evaluating the merits of proposals covering these very dissimilar reserves. In addition, reserve advisory committees will provide guidance on reserve research needs, current activities, and proposed activities from a local perspective.

Regional Marine Research Boards. In December 1990, President Bush signed the Marine Research Act (PL 101-593) to establish priorities for regional ocean and coastal research. The Act authorized eighteen million dollars per year for five years, beginning in 1991, to be administered through nine regional marine research boards (RMRB). Each RMRB was required to develop a regional marine research plan which contains:

- an overview of environmental quality and trends in the region,
- an inventory and description of all relevant research which is anticipated during the four year term of the plan,
- a statement and explanation of marine research needs and priorities in both the near and long term,
- an assessment of how the plan will incorporate certain existing research and management in the region, and
- a general description of marine research and monitoring objectives and timetables to guide the funding of projects by the relevant RMRB.

Research projects inventoried are related to water quality and ecosystem health, including topics such as circulation and water quality, living marine resources and human health, wetlands and watershed research and restoration, wildlife, and sediment transport, contamination, and dredge materials. Annual meetings and workshops are envisioned to exchange information, identify contemporary research and management priority topics throughout each region, and act as catalysts for collaboration to minimize duplication of effort amongst the numerous research organizations and agencies in each region. If provided funding, the RMRBs and their advisory committees will revise the plans as needed.

The State of California provides representatives to the Pacific Northwest RMRB (Pt. Reyes north to the Canadian border) and the Southwest RMRB (Pt. Reyes south to the Mexican border). The Southwest RMRB added marine research from Mexico to help characterize the entire Pacific Coast. Both the Pacific Northwest and the Southwest RMRBs have completed their inventories and research plans. The U.S. portion of the Southwest RMRB inventory contains over 220 records for research funded by more than 100 federal and State agencies, and the Mexican inventory contains over 100 records from nearly 30 agencies and institutions. The Pacific Northwest RMRB inventory contains almost 180 records for research funded by approximately 75 agencies and organizations.

These research plans could provide the foundation for a more extensive and comprehensive inventory of ocean and coastal research activities in California, to ensure support of the most appropriate and highest quality research for use by resource managers and decision-makers. However, the Congress has only provided funding to implement these programs in the Gulf of Maine RMRB. Such a regional effort to increase collaboration and coordination is becoming more vital with numerous organizations conducting ocean and coastal research in California, a limited understanding of the ocean ecosystem and human-induced impacts to the system, reduced funding for research at all levels, and a world of rapidly changing technologies.

Emerging Technologies

It is important to identify and facilitate the development of new or emerging ocean technologies that could assist California in its efforts to protect, manage, or sustainably develop its ocean resources. The first step toward achieving this goal is to set State research priorities that will help direct the research community toward developing new or emerging technologies. The recent revision of the policy and research needs statement for the Resources Agency Sea Grant Advisory Panel provides such guidance (see Appendix K). Three of the identified research priorities in this statement apply to future ocean technologies:

Ocean Engineering. Develop and evaluate ocean engineering methods, systems, or technologies with a focus on practical and economically viable applications to coastal and/or ocean uses. Identify economically viable and commercially useful alternative coastal and/or ocean applications of military engineering concepts, technologies, or products.

Coastal-Dependent Industry. Identify and evaluate strategies and techniques to enhance and promote the environmental sustainability of coastal and/or ocean dependent industries such as commercial ports and harbors, commercial fishing and processing, aquaculture, marine transportation, ocean engineering, tourism, recreation, and mineral extraction activities.

Marine Biotechnology. Develop and advance the tools of marine biotechnology and molecular and cellular biology for applications in pharmacology and biomedical research, aquaculture, environmental remediation, sea food safety, and other related fields.

No one can predict with any degree of certainty the types of technology development that may occur in the future. However, at the request of the Resources Agency, Dr. Richard Seymour of the Ocean Engineering Research Group at Scripps Institution of Oceanography and Texas A&M University provided some ideas regarding the ocean technology challenges that may face California and the nation over the next 20 years. These challenges, described below, include species-specific fishing technology; removing, rehabilitating or reusing offshore structures; innovative beach re-nourishment technology; energy storage; wave power extraction; preventing tanker-related oil spills; and developing offshore oil without surface platforms.

Species-Specific Fishing Technology. The by-catch of marine species other than those sought by fishermen affects the sustainability of fishery stocks. Developing gear which reduce unintentional "take" will require cross-disciplinary research, improved field observation of animal behavior, and extensive field testing.

Removing, Rehabilitating or Reusing Offshore Structures. As oil fields are depleted, existing production platforms will require removal, if their useful life has been met, or may have other uses if they are still viable. In some cases, the structures may meet the end of their service lifetimes before the oil is completely gone. In this case, re-qualification procedures will often require surveys and repair. This is a highly technical field with work in this area already being undertaken in California by a consortium of industry, government, and academic organizations.

Innovative Beach Re-Nourishment Technology. Many Southern California beaches will require substantial re-nourishment over the next several decades due to flood control measures on land, which deny sand to the beaches, and the detrimental effects of harbors and other shoreline structures on sand movement. Natural factors, such as the sometimes high loss rates of sediments down submarine canyons, also reduce sand supply to beaches. Dredging sand from offshore is expensive in California because of the great water depths and the difficult wave climate. Riverine and onshore sites for sand are limited by air quality and other environmental constraints. Possible solutions could involve the use of innovative technologies to trap sand and bypass submarine canyons or to back-pass sand to the updrift end of littoral cells. These technologies could result in lower cost and environmentally acceptable solutions for beach re-nourishment.

Energy Storage. Much of California's demand for electrical power is in areas where conventional pumped hydroelectric storage for periods of peak electrical demand is impractical or impossible. Storage of energy by compressing air is a viable alternative now being used in underground caverns in several locations around the world. Unfortunately, the local geology in California's coastal areas is seldom suitable for this storage medium. Storage of compressed air in undersea pipelines, using the hydrostatic pressure of water, offers an attractive alternative. This is especially true in locations where fossil fuel plants are already sited close to submarine canyons offering short access routes to deep water, such as Carlsbad, Manhattan Beach, and Moss Landing. The conversion equipment for this technology (such as pumps, turbines, and heat storage) has already been developed.

Wave Power Extraction. Wave energy conversion systems have been designed using a variety of engineering approaches. A major technical problem with operating these systems is matching the highly variable wave energy output with the demand for electrical power. If the problem of energy storage can be resolved using the air compression method described previously, a major impediment to the development of wave power can also be eliminated. Many promising wave power devices are better equipped to compress air than they are to rotate generators. Converting highly unpredictable wave energy into a steady or on-demand source of energy through its combination with compressed air energy storage technology could make this a high-quality energy source.

Preventing Tanker-Related Oil Spills. Increasing volumes of oil are being transported to the United States in foreign flag vessels. Vessel traffic control systems, offshore routing, and spill response technologies are obvious means for reducing the hazards of this transportation. Less obvious, but potentially as important, may be mandatory global positioning system reporting by all vessels, over-the-horizon radar systems, enhanced weather observations, and improved modeling of offshore conditions including currents, winds, waves and visibility. The latter capabilities can aid in both collision prevention and spill trajectory modeling.

Developing Offshore Oil Without Surface Platforms. Technology is now under development along the Gulf coast and in the North Sea to allow oil and gas production facilities to produce and transport fluids without the use of surface platforms. The technology, known as seafloor wellhead completions, has been in existence for some time, but not for high volume operations in deep waters. The technology under development would allow the use of seafloor wellhead completions connected to underwater pipeline systems designed to transport oil over distances of more than 100 miles. These systems are complex because of the need to accommodate the transport of unprocessed well fluids and to transport them to shore or shallow water treatment facilities. Although much work needs to be done, this approach may provide a viable alternative to permanent offshore platforms. At the same time, it creates a large market for remotely operated and autonomous vehicles (unmanned submarines) to service these wells.

Information Technology

The advance of computers in data collection, storage and analysis has been invaluable in allowing science to move forward rapidly and individual resource management agencies to become more efficient. Through the use of this technology, a tremendous amount of data from around the world continues to be made more readily accessible; however, standards for allowing easy movement of data between different collection, storage and analysis systems are still being developed. For example, past data collection methods saw city maps being drawn to one scale, while county parcel maps were drawn to another. One agency may launch a watershed management program but use a different boundary scheme than other agencies, making data sharing and comparison difficult, if not impossible. To further complicate matters, different geographic information system (GIS) software packages are unable to "communicate" with one another, so that if one agency is using a GIS with Autocad software and another agency is using one with Arc-View, they are unable to easily share information with one another, even if the data is collected in the same manner.

The most useful data is gathered and referenced to location or "geocoded" in a scaleless format (in short, data location identified by longitude and latitude) to allow easy conversion or overlay with other data sets.

As data collection methods and GIS technology become more standardized, this conversion and overlay will become easier and less expensive.

A major thrust in natural resources information technology at this time is finding ways for agencies to collect and maintain data in “real” time and making the information available to the public at little or no cost. A good example of this effort to date is the CalFed Bay-Delta Program, a joint federal-State effort which makes sampling data from the San Francisco Bay/Sacramento-San Joaquin Delta available over the Internet within two days of collection. This information is available at no charge to the user (other than any fee associated with Internet use). However, other data sets are proprietary, meaning that in order to use the underlying information, the data set must be acquired directly from the source provider, making widespread use of the data cost-prohibitive in many cases.

A long-term goal in information technology that will be most helpful to resource managers and decision makers is developing an “open” GIS, or an interchange format that allows easy movement of static and real time data between a network of computers distributed over large distances. This would allow, for instance, a resource manager to obtain data sets over the Internet from multiple agencies and overlay the data for decision-making purposes, knowing that it is the most up-to-date data available from those agencies. Today such overlaying efforts require numerous staff hours in obtaining, documenting and standardizing the data sets. In short, data still have to be brought together in a common format and at a single site, with future data having to be added as constituent data sets change. However, open GIS is many years away and decision makers must rely on current state-of-the-art GIS and information technology. Examples of cutting-edge information technology efforts related to ocean and coastal resources are the California Environmental Resources Evaluation System, DFG Statewide GIS and Monterey Bay Pilot projects, UC Santa Barbara Marine Protected Areas/GIS Project, and California Rivers Assessment.

California Environmental Resources Evaluation System. The Resources Agency of California developed and operates a computerized information system for natural and cultural resource information known as the California Environmental Resources Evaluation System (CERES). The CERES is a collaborative system designed to coordinate information about California's natural resources, directing access to and integrating information from existing systems and making it accessible to members of the public over the Internet. The CERES provides access to scientific facts, figures, and findings from data developed at state, national, and international levels, including satellite imagery and photography, environmental impact reports, and census, land ownership, vegetation, and wildlife databases. The CERES also provides access to environmental information from the Resources Agency's constituent departments and facilitates access to such analytical tools and services as geographic information systems, electronic data catalogues, ecological and economic projections, and funding or technical assistance directories. The CERES is located on the world wide web at <http://ceres.ca.gov/>.

The CERES has formed partnerships with a number of environmental data providers to work toward a seamless system for allowing broad access to environmental information, while data providers remain custodians of the information they produce. In addition to working with a number of partners, a cohesive environmental information system must work with different data types. The CERES includes text, tabular data, photographs, and geographic information system files. The challenge now is to efficiently develop and store this information for coastal and ocean areas using consistent and transferable formats so that it can be easily located, retrieved, layered and made accessible to both public and private sector users.

To this end, the Resources Agency has begun an effort in conjunction with the San Diego Supercomputer Center to integrate coastal information sets as part of an information technology strategy being developed by the CERES. One goal of the strategy is making coastal information readily and publicly available, in part for layering purposes. The CERES is working with other State agencies, universities and the private sector to develop a system of standards for data geocoding, storage, management and analysis in order to more easily integrate data sets. Ten terabytes of storage have been made available at the San Diego Supercomputer Center for this purpose.

DFG Statewide GIS. The California Department of Fish and Game is developing a statewide GIS program which will include an ocean component and be an integral part of the CERES. The program will provide a system designed, as much as possible, to be compatible with ongoing GIS development efforts by other federal, State, and local agencies, as well as academic, private and non-profit groups. Some applications assisted by the DFG's GIS effort include resources inventory and assessment, hazardous materials incident response, species/habitat relationships, environmental review, legislative analysis, DFG patrol effort assessment, project and contract tracking and planning, and land acquisition planning and management. The DFG is assembling data for the ocean component which will cover the entire 1,100 miles of California coast and provide information at a level of detail useful for addressing a variety of regional ocean and coastal management concerns.

Ocean management requires access to multi-dimensional data regarding both ocean and land resources, including data concerning air quality above the water, navigation on the surface of the water, pollution levels and presence of marine life in the water column, and the characterization of underwater geological formations. Information sources include marine resource inventories developed by federal, State, and local agencies, private industry data for ocean projects, and university data compiled during marine research efforts. For example, extensive industry data has been developed to support oil and gas development, power plant siting, offshore liquefied natural gas facilities, and offshore mineral leasing proposals. Initial categories of data being considered for incorporation into DFG's GIS ocean component include:

- Biological data on ocean (such as intertidal, benthic, kelp beds), estuarine (such as estuaries, bays, lagoons), riverine (such as aquatic communities, anadromous fish habitats, exotic fish), and terrestrial (such as native vegetation, rare or threatened species) resources.
- Physical data on winds, currents, temperatures, bathymetry, regions of upwelling, hydrography, elevations, and land uses.
- Facilities data on roads, pipelines, petroleum refineries and storage, sewage treatment plants and outfall structures, power plants, and recreational facilities.
- Consumptive uses data on commercial fishing, recreational fishing, and kelp harvesting.
- Jurisdictions data on the coastal zone, city and county boundaries, marine managed areas, DFG fish blocks, State Tidelands, the territorial sea, and the Exclusive Economic Zone.

To create an ocean decision support system which makes use of numerous multi-dimensional data sources, many technologies and software tools will be necessary. Since it may take a number of years to establish this statewide system, it was determined by the Resources Agency and DFG that the State could benefit from a regional pilot project which would be operational in a much shorter time period.

Regional GIS Pilot Project - Monterey Bay. The goal of this pilot project is to establish a complete GIS for a specific portion of the coast within one year of completing this Agenda. Monterey Bay was chosen for the following reasons:

- The Monterey Bay National Marine Sanctuary (MBNMS) was designated in 1992, with the State of California committing to providing a high level of assistance in its management. The Resources Agency of California, California Environmental Protection Agency, Coastal Commission, and DFG are currently providing assistance through the MBNMS Advisory Council. These agencies, as well as the State Water Resources Control Board and Regional Water Quality Control Board, are also represented on the MBNMS Water Quality Task Force and Policy Working Group which were established to help develop a water quality management program for the MBNMS.

- The MBNMS is blessed with an impressive diversity of unique and valuable marine resources. A substantial amount of data and information has been developed in the region that could be incorporated into a GIS and used to assist in managing the MBNMS. For example, the Coastal Commission is currently using Monterey Bay as a pilot area to conduct a Regional Cumulative Assessment Project to determine how shoreline armoring, public access, and wetlands have changed over time. This information is being used to develop future management strategies.
- Numerous organizations, such as the National Oceanographic and Atmospheric Administration, Moss Landing State Marine Lab, the Coastal Commission, UC Santa Cruz, Santa Cruz and Monterey counties, the Association of Monterey Bay Area Governments, other local governments, and local non-profit groups, have been working to develop computer-based geographic information systems. Several organizations have already indicated a desire to work with the DFG on the regional pilot project. This plethora of activity presents a unique opportunity to identify existing data, help facilitate data transfer, avoid duplication of efforts, and maximize the utility and consistency of ongoing activities in the region.

This pilot project is an opportunity to complete one phase in establishing a statewide GIS. The system will be designed at a level of detail consistent with the needs and budgetary constraints of a statewide effort. Moreover, Monterey Bay also presents some exceptional opportunities to ensure that this effort is compatible with more specific ongoing projects in the region.

One recent application of advanced technology in the Monterey Bay area is a project that uses National Aeronautics and Space Administration (NASA) satellite and overflight imagery to evaluate trends in coastal processes (i.e. erosion, modification of water courses, and vegetation changes) within the Elkhorn Slough National Estuarine Research Reserve. The Resources Agency, NASA, Coastal Commission, and Cooperative Institute for Research in Integrated Ocean Science have worked together on this project and produced detailed geographic information that could provide a model approach for future satellite imagery analyses of shoreline processes in other coastal regions of the State. This analysis complements other ongoing site-specific efforts in Elkhorn Slough, including a study by UC Santa Cruz to assess the estuarine effects of converting to sustainable agricultural practices, and hydromodification studies being conducted by the Moss Landing Marine Laboratory to determine ways to reduce erosion of valuable wetland resources in the region.

UC Santa Barbara Marine Protected Areas/GIS Project. The UC Cooperative Extension Sea Grant Marine Advisory Program is creating a database of California marine protected areas (MPAs) to assist resource managers, researchers, and resource users in better understanding California's MPAs. The Sea Grant Extension Program is also using the database to create a GIS for all California MPA boundaries, in cooperation with the Geography Department Remote Sensing Research Unit at UC Santa Barbara. When completed this information will be made available through a published guide and in a variety of computer formats, including through the Internet. Funded by the UC Sea Grant and the David and Lucile Packard Foundation, this project will provide a good start in helping resource managers and the public better understand and manage California's complex assemblage of ocean and coastal managed areas. It will also provide an offshore information "layer" for use with other data sets.

California Rivers Assessment. The California Rivers Assessment (CARA) is an effort to assess the environmental conditions of California's rivers, which play a role in determining the health of California's ocean ecosystem. This effort is using the best existing data and information from many contributors, with a goal of improving river conservation and management by making this information available and useful to decision makers and the public. Initiated in 1992, CARA is a cooperative effort between the Resources Agency and the National Park Service's Rivers, Trails and Conservation Assistance Program. Substantial funding is provided by the Wildlife Conservation Board (WCB), with overall management provided by WCB's Riparian Habitat Conservation Program. The project receives additional funding from the U.S.

Environmental Protection Agency, and technical support from UC Davis and the DFG. CARA has also attracted participation from over 30 public agencies and private organizations.

This effort is establishing a database and GIS for California's approximately 140 river basins using the U.S. Environmental Protection Agency's river reach files as the base layer. Conducted in several phases with an initial emphasis on riparian and aquatic habitat information, the most significant result will be an aggregated information model (AIM) which incorporates over 60 databases and GIS layers, including vegetation, land ownership, dams, water quality, rare and endangered species, legislative districts, soil and farmland inventories, wetlands designations, and native fish. The AIM allows users to create and download custom maps from GIS layers by providing a query system over the World Wide Web called "ICE MAPS." The CARA may be accessed through the CERES Homepage at <http://ceres.ca.gov/>.

FINDINGS AND RECOMMENDATIONS

Finding

California has high quality ocean and coastal education curricula and programs, but lacks a central directory to identify them. Educators and students frequently have difficulty identifying existing or developing curricula and organizations that focus on ocean or coastal education. Teacher training and enhancement opportunities in marine education also abound. Although excellent guides have been developed to distribute this information, a centralized directory available through the Internet would provide even greater access.

Recommendation H-1. ***Develop and make available through the Internet a central directory of ocean and coastal educational organizations, educational resources, and teacher training and enhancement opportunities in California.*** This directory should include, at a minimum, curricula and programs available for K-12, college and university programs, and the resources available in each program. The directory would need to be updated regularly and should be made accessible through the California Environmental Resources Evaluation System. Such a directory could also be used to identify programs which should be enhanced or expanded and where new ones should be developed.

Finding

Although California's colleges and universities have substantial ocean science research and education capacities, they lack an ocean and coastal policy graduate education program. California has had to reconcile major policy questions over the years concerning a variety of ocean and coastal development proposals and marine resource management disputes. Ocean policy graduate education programs currently exist in other states and, although some courses are offered at California institutions, a full interdisciplinary program at the graduate level has yet to be established.

Recommendation H-2. ***Develop an ocean and coastal policy graduate education program within California's private or public colleges or university systems.*** Developing such a program will help maintain California as a leader in ocean policy and management. California has extensive expertise in the policy, scientific, and legal aspects of ocean and coastal management which could be used to develop one or more such programs within the State.

Finding

Ocean resource management and policy-making requires scientific data regarding habitat functions and values, species diversity, and other complex physical, biological, and chemical processes which affect the health of California's ocean ecosystem. Understanding these and human-induced factors which affect ocean ecosystem health is fundamental to the process of developing sustainable ocean resource management policies and for guiding the development of new technologies. Limited State funds must be directed toward research projects which improve our understanding of these complex issues. California lacks a comprehensive listing of current or recent ocean and coastal research activities either being conducted by or funded through the State of California, or through private funding. This information is needed to determine what research categories have received priority in the recent past, and where limited State funds should be spent in the future.

Recommendation H-3. The RASGAP, in cooperation with the recommended Ocean Resources Management Coordinating Council (see Chapter 6), should annually prepare a list of the highest priority ocean and coastal research needs for State funds. Proposed research projects which are consistent with this priority list will be given substantially greater consideration for State funding. To provide the most accurate and timely information on which to base this prioritization, a system must be established for collecting, categorizing and analyzing recent, current and future ocean and coastal research activities pertinent to California, focusing initially on State-funded research. Some of this work has been completed by the Northwest and Southwest Regional Marine Research Boards for marine water quality and ecosystem health research conducted during the early 1990s. This information base should be expanded upon for a more complete inventory and could be conducted in cooperation with the Regional Marine Research Boards, if federal funding for these programs was continued.

Finding

California has been a leader in developing ocean technologies by proactively seeking and promoting their research and development. Much of this research and technology development was the result of expenditures by the military and offshore oil and gas industry, both of which have substantially reduced expenditures on such research. New developments in ocean-related energy generation and storage, low-polluting energy sources, biotechnology, shipping safety, submersible technology, and communications can provide substantial benefits to society if fully developed. These developments can be stimulated through joint federal, state, and industry partnerships.

Recommendation H-4. Promote continuing research into emerging ocean technologies and develop the government/private sector partnerships to carry out these research initiatives. The California Sea Grant Program can provide a start, but new initiatives with substantially higher levels of public and private investment should be explored to stimulate new technology research. In addition, ocean information and technology not previously available to the public is now being released by the U.S. Navy and other government and private sector organizations, and could provide valuable data for new technological developments.

Finding

California will benefit substantially by developing and using innovative technical approaches to increase our understanding of California's ocean ecosystem, as well as developing methods to display,

analyze, and communicate this information. These technical innovations will improve the efficiency and effectiveness of California's ocean ecosystem management, especially if pursued in a coordinated and strategic fashion with other states, the federal government and private industry. The pilot geographic information system (GIS) being developed by the California Department of Fish and Game, combined with other GIS development efforts, will demonstrate many applications of this technology for ocean management efforts.

Recommendation H-5.

In cooperation with the State Office of Information Technology, the CERES program should complete a comprehensive information technology strategy for natural resource data collection, storage and analysis. Developing a statewide ocean and coastal resources GIS should be a top priority in such a strategy, as it will provide an important tool for ocean and coastal resource management.